EEAP 243
Lab 11

Lab Work:
Questions Due:

FET CHARACTERISTICS, AMPLIFIERS, AND APPLICATIONS

READING ASSIGNMENT: Horowitz, pgs.223-231, 232-234, 240-241.

Abstract:
In this lab you will compare methods for measuring the dc characteristics of an N-channel JFET. The performance of a FET current source will be examined. The common source and common drain amplifiers will be studied.

Part 1 - DC Characterization

In this part, you will use determine your transistor's I_{DSS} and V_P by using the curve tracer and by direct measurement. You can use the curve tracer any time during your lab period, so don't waste time standing in line.

(1) Set the curve tracer to the default drain characteristic settings listed in ~~Figure~~ Table 1.

CONTROL	DEFAULT SETTING	DESCRIPTION
13	*	- set so display starts at point labeled 9
12	2 mA	I_D - drain current per vertical cm.
15	2 collector	V_{DS} - drain voltage per horiz. cm.
20	in	gate voltage polarity inverted
17	0.5 V	V_{GS} - gate voltage increment per step
all others	NPN default positions	

~~Figure~~ Table 1 Curve tracer settings for characterizing FETs

(2) Test the reference transistor to make sure you have the settings right.
(3) Display your transistor's drain characteristics and adjust the controls as needed to get a nice display. ACCURATELY record the characteristics in Table 11.1. Pay particular attention to the slopes of the curves in the resistive and saturation regions.
(4) Set the curve tracer to the default transfer characteristic settings listed in ~~Figure~~ Table 2.

CONTROL	DEFAULT SETTING	DESCRIPTION
13	*	- set so display starts at point labeled 9
12	2 mA	I_D - drain current per vertical cm.
15	steo gen	V_{DS} - drain voltage per horiz. cm.
20	in	gate voltage polarity inverted
17	0.5 V	V_{GS} - gate voltage increment per step
all others	NPN default positions	

~~Figure~~ Table 2 Curve tracer settings for measuring the transfer characteristics of FETs

(5) Test the reference transistor to make sure you have the settings right.

SAVE A XEROX OF YOUR DATA FOR LAB #12

(6) Display your transistor's transfer characteristics and adjust the controls as needed to get a nice display. ACCURATELY record the characteristics in Table 11.2. The curve will be a set of points rather than a continuous curve. Pay particular attention to the horizontal (V_P) and vertical (I_{DSS}) axis intercepts. } do

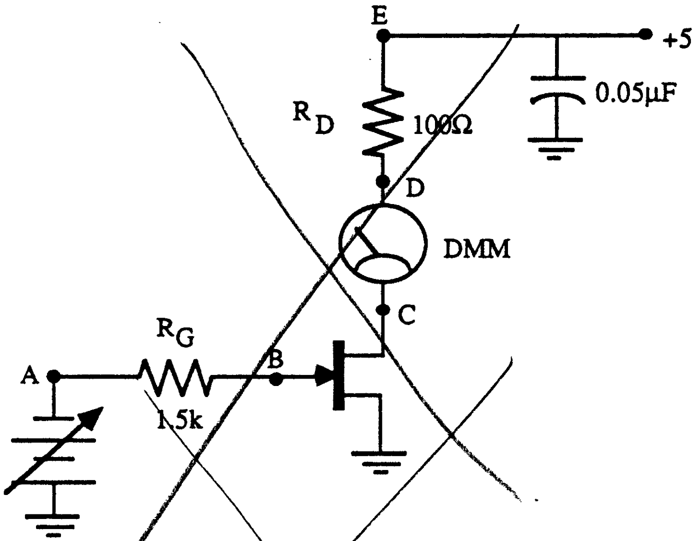


Figure 1 - Circuit for characterizing FETs

~~(7) Build the circuit shown in Fig.1.~~
~~(8) Adjust the variable supply so that the DMM reads approximately 1 µA.~~
~~(9) Remove the DMM and use it to measure V_{GS}, which is very nearly V_P. Record your results in Table 11.3~~
~~(10) Put back the ammeter (DMM), remove the variable supply, and ground point A.~~
~~(11) Record I_D, which is I_{DSS}. The current may slowly decrease due to heating of the transistor, so take your reading quickly. Record your results in Table 11.3.~~

FETs are commonly used as current sources for circuits found on IC's. Consider the FET current source shown in Figure 2.

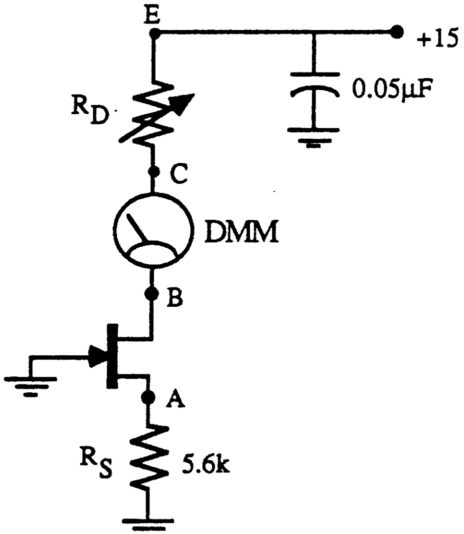


Figure 2A FET current source

1. ~~Build the circuit of Figure 2A. Use your RSB for R_D.~~
2. ~~Measure I_D for R_D values of 10k, 20k, 30k, 40k and 50k. Record your measurements in Table 11.4.~~
3. ~~The constant current should break down when V_{DS} is near $-V_P$. Take additional data near this breakdown point. Record your data in Table 11.4.~~

Part 2 - AC Characteristics

Start here

The value of g_m for the FET is much more variable than β_o was for the BJT. The gain of an FET amplifier is very dependent on its operating point. Follow these steps to characterize the AC operation of your transistor. You should notice if the CH2 waveform ever becomes distorted.

1. Build the circuit shown in Fig.2B. Connect scope CH1 to point A and CH2 to point C. Adjust the generator to produce a 100 mV_{p-p} 1 kHz triangle wave at point A.
2. Adjust the generator's DC offset so that point A is at approximately +1.0 V DC.
3. Use the scope to measure the AC_{p-p} voltage at point C. Record your data in Table 11.5.
4. Repeat steps 2 and 3 using +0.5 V, 0.0 V, -0.5 V, -1.0 V, -1.5 V, etc. in step 2 until you reach your transistor's V_P.
5. Set the generator's DC offset so that point A is at +1.0 V DC. Use the DMM to measure the DC voltage at point B. Record your result in Table 11.5.

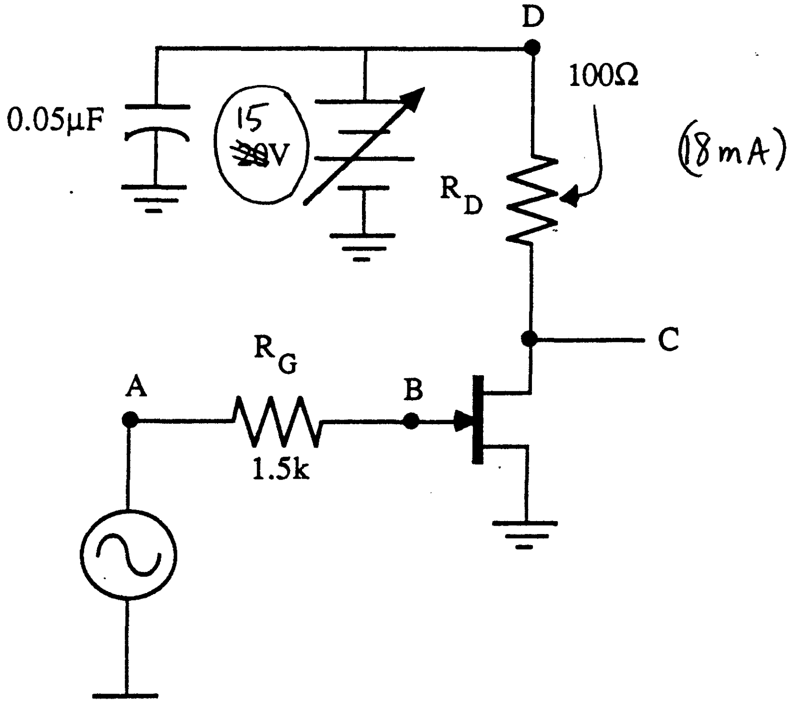


Figure 2B - FET amplifier

The FET can be used in the common gate, common source mode, or common drain just as a BJT can operate in the common base, common emitter or common collector modes. The common source amplifier configuration of Figure 2 is usually used for voltage amplifiers; however, when impedance matching or high output power is a consideration the source follower (also called the common drain) configuration is usually employed.

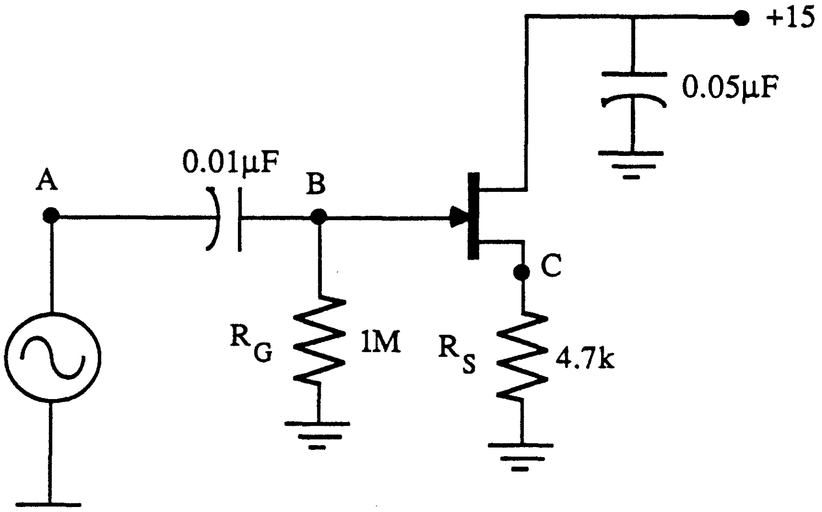


Figure 3 - Source follower

and
(B)

(1) Build the circuit shown in Fig.3. Connect the scope CH1 input to point A and CH2 input to point C. Use your DMM to measure the DC potentials at points (A) and C. Record these values in Table 11.6.
(2) Adjust the generator to produce a 100 $mV_{p\text{-}p}$ 1 kHz triangle wave at point A.
(3) Use the scope to measure the $AC_{p\text{-}p}$ voltage at point C. Record your data in Table 11.6.
(4) Repeat steps 2 and 3 using 200mV, 400 mV, etc. in step 2 until your signal begins to distort.
(5) Connect a 1000 ohm resistor between point C and ground. Repeat steps (2) and (3).

The performance of many FET amplifiers can be improved by using current biasing. Modify your circuit to that of Figure 4 which is a source follower with a current source load.

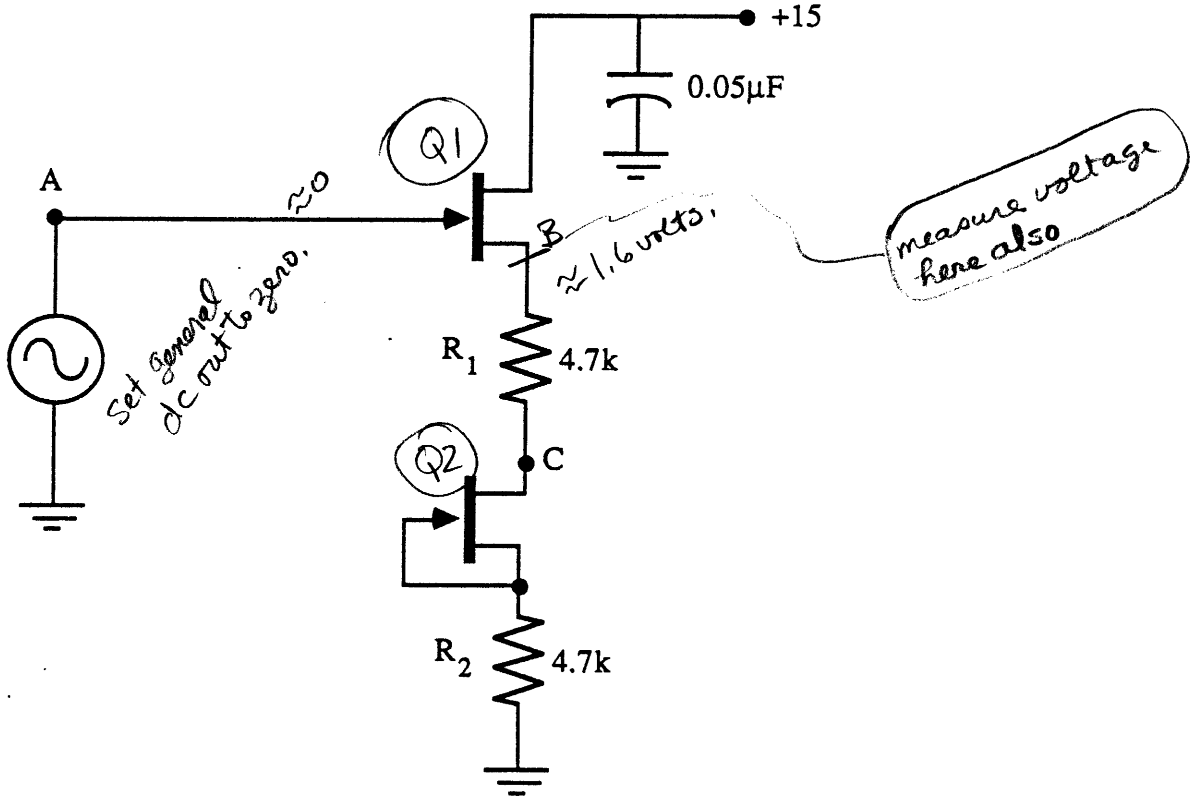


Figure 4 - Source follower with common source load

(1) Build the circuit shown in Fig.4. Connect the scope CH1 input to point A and CH2 input to point C. Measure the DC voltages at points A and C. Record your measurements in Table (11.7)
(2) Interchange your FETs. Remeasure the DC voltages at points A B and C. Record your results in Table 11.7. (3)
[illegible] Adjust the generator to produce a 100 $mV_{p\text{-}p}$ 1 kHz triangle wave at point A.
(4) Use the scope to measure the $AC_{p\text{-}p}$ voltage at point C. Record your data in Table 11.7.
(5) Repeat steps 3 and 4 using 1V, 1.5V, etc. in step 3 until your signal distorts.
(6) Connect a 1000 ohm resistor between point C and ground. Repeat steps (3) and (4).

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE CONTINUING.

Questions:

1. (a) What values of I_{DSS} and V_P were indicated by the curve tracer?
   ~~(b) What values of I_{DSS} and V_P were found [illegible] data of Ta[illegible]~~
   (c) What are the values for I_{DSS} and V_P on the data sheet?
   (d) What is your most accurate estimate of each parameter? Why?

2. You recorded your transistor's drain characteristics using the curve tracer. The slopes of these characteristics in the saturation region are not zero, indicating the presence of an FET parameter called g_d.
   (a) Use your knowledge of the BJT model to draw a FET small signal model which includes g_d. Write an equation for g_d.
   (b) Calculate the value of g_d for each of your curves.
   (c) Compare g_d at $V_{GS} = 0$ to the data sheet value of g_{os}.

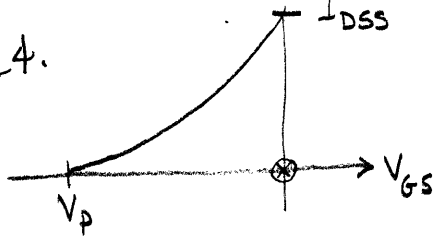
$$\frac{1}{g_d} = \frac{\Delta I_D}{\Delta V_{GS}}$$

using a linear approximat.

3. (a) Use your data of Table 11.5 to make a graph of g_m vs V_{GS}.
   (b) Use your drain characteristics from Part 1 to make a similar graph of g_m vs V_{GS}.
   (c) Compare g_m at $V_{GS} = 0$ to the data sheet value of g_{fs}.
   (d) What was unusual about the voltage at B when you used +1.0 V? Why?

~~4. No question about Figure 4.~~

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$



$\sim 125 \mu ℧$

$\boxed{\approx 8 k\Omega}$

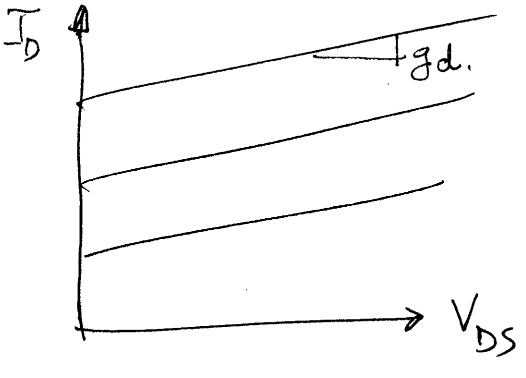
Hint: what was your relationship with V_p ?

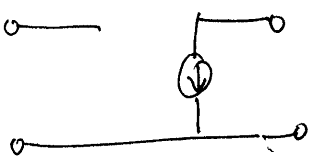
$$g_{fs} \triangleq \frac{\Delta I_D}{\Delta V_{GS}}$$

small-signal transconductance with common source amp.

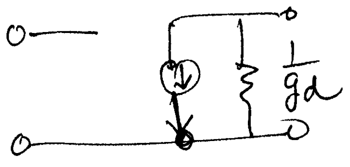
$g_{fso} = g_{fs}|_{V_{GS}=0}$.

4. Need question about Figure 4.





$$\frac{1}{r_d} = \text{slope} = \frac{\Delta I_D}{\Delta V_{DS}}$$



EEAP 243 LAB 11 EVALUATION

NAME (print)__________________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

What will be the gain (don't forget the sign) from point A to point B in Fig. 11.2 if we halve/double the resistance of $R_1/R_2/R_3$?

The gain will be __________.

Question #2

What will be the gain (don't forget the sign) from point A to point B in Fig. 11.4 if we halve/double the resistance of $R_1/R_2/R_3$?

The gain will be __________.

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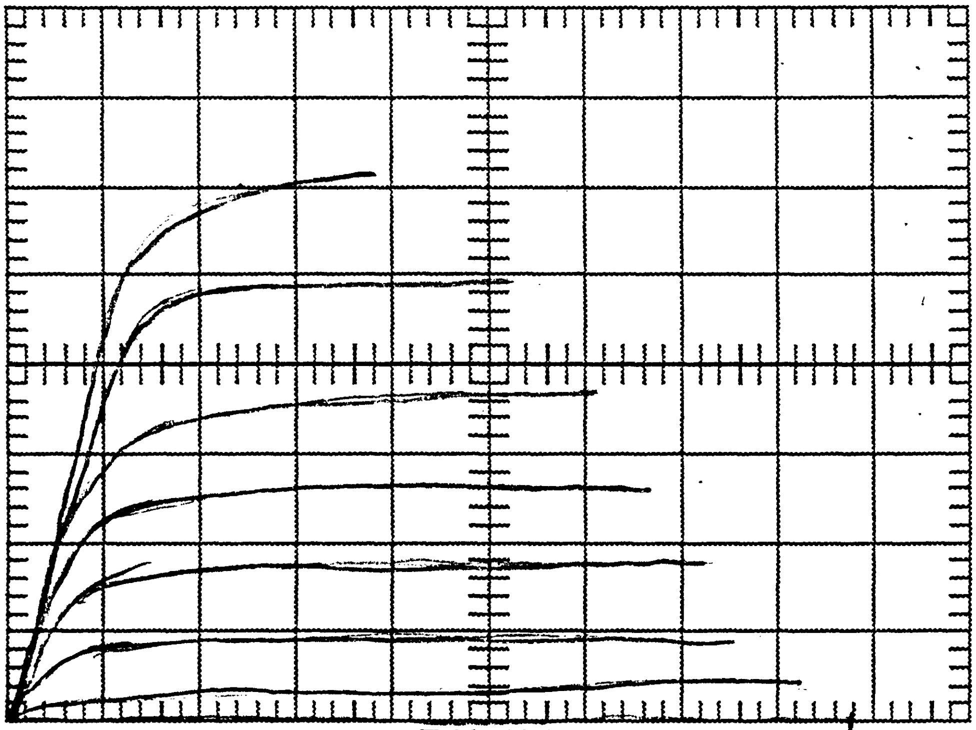
NAMES: ____

Lab 11 Data



go to 10

Table 11.1

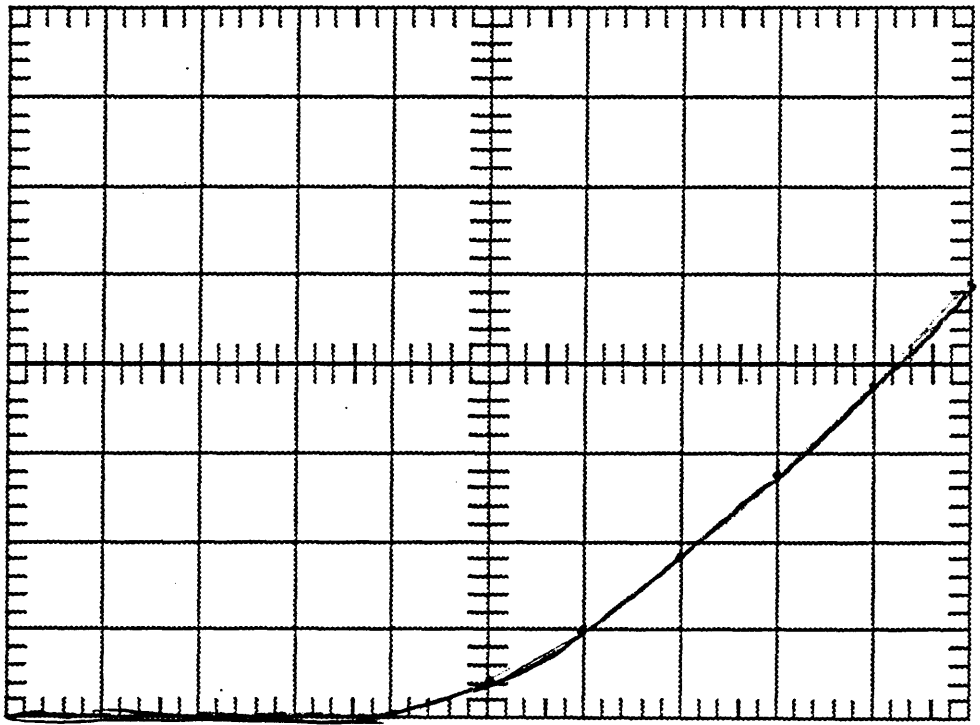


Table 11.2

Difficult to keep at 1mA

V_{GS}: −3.55 V I_D: −1.[illegible] μA

Table 11.3 DC FET characteristics

I_{DSS} = −11.11 mA.

R_D	I_D mA	
10k	~~0.574~~	0.529
20k	~~0.194~~	0.513
30k	~~0.142~~	0.415
40k	~~0.110~~	0.332
50k	~~0.090~~	0.267
9k		0.530.
60k		0.272
70k		0.249

+1.0   1.4x50 mV → V_B = 0.696 V

Table 11.4 FET current source characteristics

V @ A	Output Voltage (p-p)
+0.5	1.3x50 mV
+0.0	1.0x50mV
-0.5	1.0x50mV
-1.0	0.9
-1.5	0.8
-2.0	0.7
-2.5	0.6
-3.0	0.44
-3.5	1.1x5mV
-4.0	
-4.5	
-5.0	
DC V_{GS}:	

Table 11.5 AC FET characteristics

V_{GATE}: 0.0 V.

V_{SOURCE}: 2.99 V (≈3.0 V)

$V_{input,p-p}$	$R_L=\infty$ $V_{output,p-p}$	$R_L=1k$ $V_{output,p-p}$
100mV	100 mV	1.45×50
200mV	200 mV	145 mV
400mV	360	300 mV
800mV	3.8×0.2	500 mV
1.2V	2.1×0.5	
1.4V	≥1.35	
1.6V	≥1.35	
1.8V	1.7	
2.0V	~1.8	

Table 11.6 Source Follower characteristics

o/p flatten at bottom after 8V

o/p distortion after

3.6×2 = 7.2 V

	Original	Reversed
V_{GATE}:	6.9mV	6.9 mV
V_{SOURCE}:	1.621 v	1.523 v

$V_{input,p-p}$	$R_L=\infty$ $V_{output,p-p}$	$R_L=1k$ $V_{output,p-p}$
100mV	50 mV	0.3×50mV
1.0V	0.5 V	0.3×0.5
1.5V	0.75	0.3×0.5
2.0V	1.0	0.3×
2.5V	1.25	0.3×
3.0V	1.5	0.3×

Table 11.7 Source Follower characteristics

signal distorts after 7.0V

o/p. distortion after 7.2 V

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NAMES: ____

Lab 11 Data

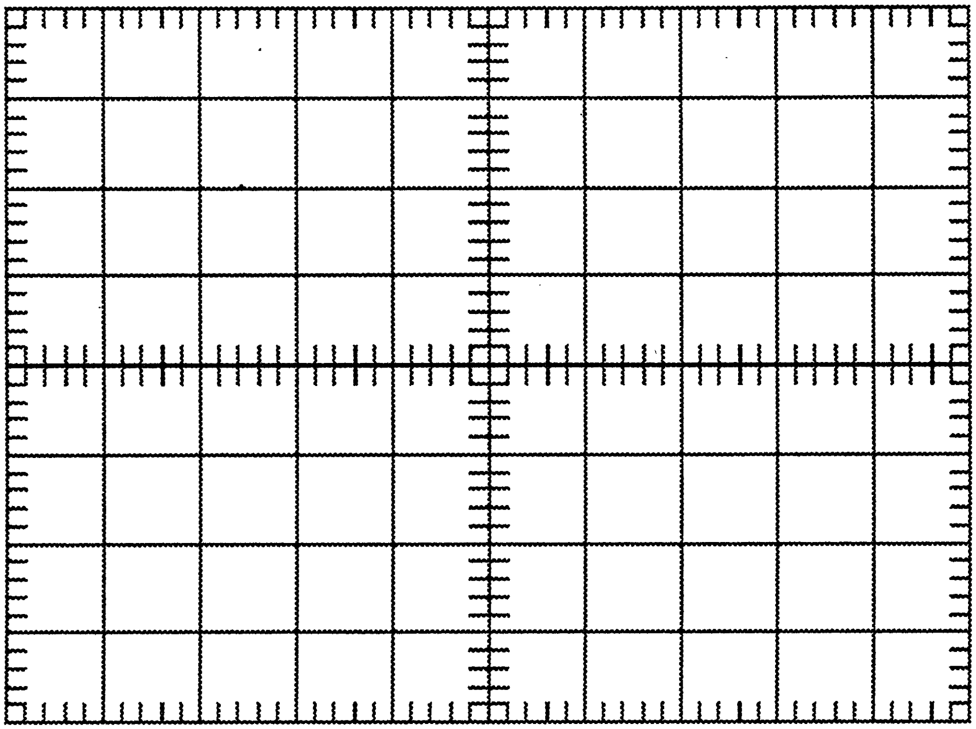

Table 11.1

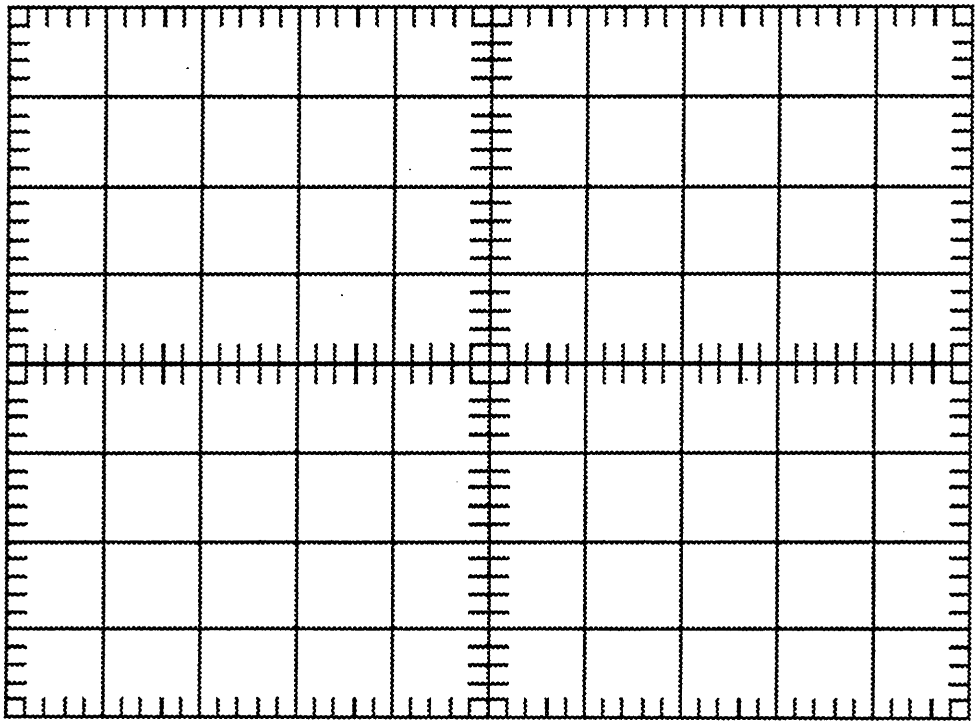

Table 11.2

V_{GS}: ____________ I_D: ____________

Table 11.3 DC FET characteristics

R_D	I_D
10k	____________
20k	____________
30k	____________
40k	____________
50k	____________
_______	____________
_______	____________
_______	____________
_______	____________
_______	____________

Table 11.4 FET current source characteristics

V @ A	Output Voltage (p-p)
+0.5	____________
+0.0	____________
-0.5	____________
-1.0	____________
-1.5	____________
-2.0	____________
-2.5	____________
-3.0	____________
-3.5	____________
-4.0	____________
-4.5	____________
-5.0	____________
DC V_{GS}:	____________

Table 11.5 AC FET characteristics

V_{GATE}: __________

V_{SOURCE}: __________

$V_{input,p-p}$	$R_L=\infty$ $V_{output,p-p}$	$R_L=1k$ $V_{output,p-p}$
100mV		
200mV		
400mV		
800mV		
1.2V		
1.4V		
1.6V		
1.8V		
2.0V		

Table 11.6 Source Follower characteristics

	Original	Reversed
V_{GATE}:		
V_{SOURCE}:		

$V_{input,p-p}$	$R_L=\infty$ $V_{output,p-p}$	$R_L=1k$ $V_{output,p-p}$
100mV		
1.0V		
1.5V		
2.0V		
2.5V		
3.0V		

Table 11.7 Source Follower characteristics